# NOTES ON TROCHUS NILOTICUS

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CONTENTS



## 1. INTRODUCTION.

*Trochus niloticus* is a primitive gastropod belonging to the Rhipidoglossa. In Queensland it is found on all the reefs and cays of the Great Barrier Reef, and its attendant lagoon channel, from Mackay to the New Guinea coast, as well as on many of the continental islands in this area and in the Torres Straits. The islands of the East Indies, the Coral Sea, New Guinea, Fiji and New Caledonia also produce it in large numbers. On the northern shores of West Australia it is found in much smaller numbers. It appears to be confined to the Tropical West Pacific and the Indo-Pacific regions.

Throughout this paper wherever *Trochus* is mentioned it is intended to refer solely to the species *T. niloticus*.

I desire here to record my thanks to the late Premier of Queensland, the Hon. W. McCormack, for giving me the opportunity to leave Brisbane with the Expedition, to Prof. E. J. Goddard for advice and the loan of apparatus, and to various fellow-members of the Expedition for advice and assistance.

## 2. DESCRIPTION.

The anatomy of the European species of *Trochus* has been studied by Robert (1900) and Randles (1904). A description of the shell of *Trochus niloticus* together with some excellent photographs was published by Hedley (1917), so that it need not be given here. His statement that there is a grotesque expansion of the last whorl of a *Trochus* shell,

however, applies only to those shells which are over 8 cm. in diameter. Up to that size the shell is straight-sided.

When the animal is examined in its shell, but with the foot and body protruded as in walking, there is seen a very large foot, which bears sensitive papillae over the greater part of its upper surface. The epipodium bears fine retractile cylindrical tentacles, six on each side, each arising from a small notch or indentation. The foot can be grooved from front to rear, so that the two sides become apposed when the animal retracts within its shell. On the posterior part of the foot is a brown, horny operculum.

The head bears a pair of tentacles, a pair of ocular peduncles, a pair of cephalic lobes and a small muzzle, very short and non-retractile. The mouth is terminal and the lower part is cleft, giving the appearance of two lateral lips. Within the buccal cavity is a many-toothed radula, typical of all " scraping " gastropods (Yonge, 1928). This works over two cartilaginous plates situated on the floor of the buccal cavity. In action the radula is forced through the mouth, which loses its slit-like form and becomes rounded. The radula is drawn from top to bottom of the mouth, giving a final upward lick just as the lips close.

On the outer side of the shell-mouth—that is, on the left side of the animal—there can be extruded a portion of the mantle, which, folding slightly, forms temporarily a short exhalent siphon, while on the inner side of the body near the columella there is a similarly formed inhalent siphon.

When the animal is taken from its shell most of the principal organs can be seen through the thin mantle. The most noticeable feature is the coiled stomachal caecum, which, being brown and approximately the size of a threepenny-piece, stands out just anterior to the liver.

There is no external difference in the structure of the animals such as would enable one at a glance to differentiate male from female. It was thought that there might be some difference in shell-form in the two sexes—for example, the relation between diameter and height—but after some hundreds of shells had been measured and examined it was found that no such difference exists. The normal method of ascertaining the sex is to break the apex of the shell and examine the gonad. In mature or nearly mature animals thus broken the sex can be told at once, males having a white or creamy-white gonad, whereas in females it is green to dark green. In immature animals the sexes cannot be distinguished by eye. This method of breaking the shells is wasteful, as all animals so treated soon die.

## 3. HABITAT.

*Trochus* on Low Isles occurs in great numbers on those edges of the reef that are open to the direct action of the dominant South-east seas. From the map of Low Isles it will be seen that, owing to the peculiar arrowhead shape of the island, the influence of these seas is felt over that portion of the island commencing at the north-east spit, passing through the east and south, and extending to the south-west corner. A few animals are to be found on the other edges, the moats, and the reef-flat, but they are not present in sufficient numbers in these places to warrant their being fished.

In general, the animals occur on the weather side of reefs, but where the reefs are narrow they are more or less evenly distributed. They shun, however, the sandy and the " grassy " localities.

It was found in attempting to keep these animals in captivity that they require the highest possible conditions of aëration, together with an abundance of food. These conditions, and also the absence of mud and silt, obtain on the weather side of reefs, so that these areas are the ideal home for *Trochus*.

On the boulders along the reef-edges rich growths of algae occur, and it is upon these plants that *Trochus* feeds. The small plants are rasped off the rocks and shingle by means of the many-toothed radula, and the scraped-off food is drawn into the mouth, sand-grains, together with foraminifera and other small animals, being also swallowed.

*Trochus* is a littoral animal, though an occasional example has been found in deep water. The greatest recorded depth is that of 12 fathoms, given in the "Challenger" Report (Watson, 1886), but it is not stated whether the specimen was living when found. Traverses were run out into deep water at Low Isles, and not one *Trochus* was found in, or reported from, water more than 3 ft. deep at lowest springs. The majority occur between the level of high-water neaps and the lowest springs mark. It is therefore quite common to find these animals exposed by the tide, though some are never out of water.

There appears to be a certain zoning of the animals. At the high-neaps mark on the shingle beach the smallest forms are found, those up to 2 cm. in diameter being commonest. These are generally found in, or close to, runnels formed by the water from the moat escaping through the shingle. In these runnels algae are very common, so food is plentiful. Next are found the 3 and 4 cm. animals, in such a position that they are bared by moderately low tides. Then come slightly larger forms, dominant amongst them being the 5 and 6 cm. ones; and lastly come the largest animals, these being bared only by the lowest springs. The absence of large forms from Low Isles reef is due to the continuous fishing by the *Trochus* hunters.

Despite this general statement there is frequently to be found a mixing of forms at the lowest springs mark, for, in suitable spots, such as that presented by a large flat slab or gnarled boulder, animals ranging from 2 to 9 cm. in diameter have been observed.

*Trochus* is gregarious, the main reasons for the animals gathering together being the presence of abundant food and ample hiding spaces in and under the boulders. On several occasions as many as 15 animals were taken from one slab or boulder. Generally the size of the animals in these communities is remarkably uniform, though there are exceptions.

At low water those animals left high and dry on the shore are exposed for some hours. In these circumstances they creep into crevices in the boulders or hide below them. For many hours they can survive thus; in fact, *Trochus* kept out of water but in the shade for two days completely revived after being returned to the sea.

When covered by the sea *Trochus* scatters over the shingle and boulders. Feeding appears to proceed at every opportunity, so that the amount of faecal matter deposited is very great. This faecal track has often been the means of tracing an animal that was otherwise hidden.

In order to see whether *Trochus* is sedentary or given to wandering, 80 animals, ranging in diameter from 2 to 5 cm., were file-marked, numbered and instantly liberated at the spot from which they were taken. Each was measured in order to keep a record of actual growth. In the first month 53 were present, for the second month 27 were found, and for the third only 21 were seen. Many immigrants were found to have arrived, showing that there was sufficient food to maintain the original inhabitants had they stayed.

It would appear from this experiment that the animals move freely about the reef. Some of the animals had moved as much as 50 yards from the original rocks, but this distance has frequently been exceeded in one night by specimens placed in a small lagoon close to the island in readiness for examination next morning.

## 4. GROWTH RATE AND AGE.

In order to find the rate of growth of *Trochus* the following methods were adopted :

(1) The measurement of marked and numbered animals confined in cages.

(2) The monthly measurement of some 600 free-living animals found on the south-east edge.

(3) The measurement of specially marked animals living freely on the south-east edge.

The first experiment was commenced in the last days of July, 1928. Two enclosures of wire-netting were constructed in a runnel from the western moat. The shape of the cages was roughly hexagonal, with sides of approximately 6 yards. In one of these enclosures 90 animals of various sizes were placed, while in the other 50 small animals were imprisoned.

Each month these animals were measured, and at the same time fresh alga-coated rocks were supplied. In October 60 of the larger and 44 of the smaller were present. A dwindling in November was followed by the almost complete destruction of the animals in December, only 1 small and 8 large specimens being found, though many broken shells were collected. Sting-rays, which made their appearance on the reef-flat in large numbers about this time and had been observed in the enclosures, hermit crabs, especially the red *Dardanus megistos*, and whelks, were without doubt responsible for much of the havoc, though a small percentage of the *Trochus* escaped over the walls of the enclosures.

Each shell was file-marked, the mark being placed on the whorl directly above the mouth of the shell. At the time of measuring and marking each shell was numbered. It was found that lead-pencil marks, if placed on the nacreous layer within the shell-mouth, would stand for a considerable time, so this means of numbering each shell was adopted. This number was soon hidden, for the growth of the shell shifted the aperture, therefore at each measurement the number was renewed.

In measuring the shell the greatest diameter was adopted as standard. This was obtained by placing the shell between the jaws of sliding vernier calipers, and measuring the base of the shell from the aperture over the columella to the opposite side.

A list of these measurements is here given, from which it will be seen that the average increase for the four months, from July to November, was approximately 2 mm. per month.

After the failure of this growth-rate experiment it was decided to commence a new series of experiments, and the measurement of approximately 600 free-living animals found on the south-east reef-edge was carried out in December and each month thereafter, the final reading being taken in July.

These animals were merely measured, and then replaced as nearly as was practicable in the place from which they had been taken. In order to avoid measuring the same animal twice, the inside of the mouth of each shell was scored with pencil at the time of

measuring. This mark, besides preventing the duplicating of readings in any month, gave the information that that animal had been seen the previous month.

The ground covered in this experiment was about 500 yards in length, and the same area was always worked over each month.

The results of these measurements are given in Table III. The measurements were divided into groups with a difference of 0·20 cm. For example, all those diameters between 2·21 and 2·40 cm. inclusive were placed in the one group known as the 2·40 group. Since the number measured each month varied, although it was never less than 600, percentage frequency has been given.

TABLE I.—*Larger Forms. Showing Monthly Measurements of Greatest Diameter and Total Increase (in centimetres) after Four Months.*

| No. | July. | August. | September. | October. | November. | Increase. |
|---|---|---|---|---|---|---|
| 1 | 2·92 | 3·09 | 3·40 | 3·69 | 3·97 | 1·05 |
| 2 | 3·12 | 3·22 | 3·50 | 3·71 | 3·96 | ·84 |
| 3 | 3·00 | .. | 3·60 | .. | 3·96 | ·96 |
| 4 | 3·20 | 3·27 | 3·55 | 3·85 | 4·05 | ·85 |
| 5 | 3·28 | 3·39 | 3·41 | 3·64 | 3·95 | ·67 |
| 6 | 3·47 | 3·65 | 3·85 | 4·07 | 4·22 | ·75 |
| 7 | 3·51 | 3·64 | 3·83 | 4·14 | 4·40 | ·89 |
| 8 | 3·51 | 3·74 | 4·00 | 4·20 | 4·45 | ·94 |
| 9 | 3·54 | 3·69 | 3·95 | 3·97 | 3·99 | ·45 |
| 10 | 3·62 | 3·69 | 3·98 | 4·25 | 4·33 | ·71 |
| 11 | 3·66 | 3·77 | 4·05 | 4·24 | 4·44 | ·78 |
| 12 | 3·73 | 3·82 | 4·05 | 4·23 | 4·50 | ·77 |
| 13 | 3·73 | 3·89 | 4·05 | .. | 4·42 | ·69 |
| 14 | 3·73 | 3·85 | 4·12 | 4·37 | 4·51 | ·78 |
| 15 | 3·75 | 3·82 | 4·09 | 4·37 | 4·67 | ·92 |
| 16 | 3·77 | 3·80 | 4·00 | 4·19 | 4·43 | ·66 |
| 17 | 3·78 | 3·90 | 4·05 | .. | 4·60 | ·82 |
| 18 | 3·84 | 3·96 | 4·10 | 4·40 | 4·59 | ·75 |
| 19 | 3·87 | 3·91 | 4·34 | 4·57 | 4·75 | ·88 |
| 20 | 4·04 | 4·10 | 4·34 | 4·63 | 4·83 | ·79 |
| 21 | 4·08 | 4·16 | 4·46 | 4·76 | 4·90 | ·82 |
| 22 | 4·10 | 4·20 | 4·44 | 4·68 | 4·87 | ·77 |
| 23 | 4·10 | 4·21 | 4·47 | 4·68 | 4·94 | ·84 |
| 24 | 4·11 | 4·16 | 4·35 | 4·53 | 4·59 | ·48 |
| 25 | 4·17 | 4·22 | 4·44 | 4·65 | 4·85 | ·68 |
| 26 | 4·22 | 4·28 | 4·52 | 4·74 | 4·92 | ·70 |
| 27 | 4·28 | 4·40 | 4·56 | 4·85 | 5·10 | ·82 |
| 28 | 4·35 | 4·38 | 4·59 | 4·79 | 4·92 | ·57 |
| 29 | 4·39 | 4·46 | 4·76 | 4·84 | 4·87 | ·48 |
| 30 | 4·41 | 4·50 | 4·74 | 5·00 | 5·13 | ·72 |
| 31 | 4·41 | 4·55 | 4·75 | 5·02 | 5·20 | ·79 |
| 32 | 4·45 | 4·52 | 4·71 | 4·98 | 5·17 | ·72 |
| 33 | 4·48 | 4·55 | 4·69 | 4·87 | 5·02 | ·54 |
| 34 | 4·64 | 4·72 | 4·91 | 5·08 | 5·18 | ·54 |
| 35 | 4·65 | 4·75 | 4·95 | 5·09 | 5·23 | ·58 |
| 36 | 4·66 | 4·72 | .. | 5·02 | 5·05 | ·39 |
| 37 | 4·75 | 4·88 | 5·05 | 5·07 | 5·20 | ·45 |
| 38 | 7·96 | 8·02 | 8·08 | 8·11 | 8·18 | ·22 |
| 39 | 8·30 | 8·33 | 8·34 | 8·34 | 8·34 | ·04 |

TABLE II.—*Small Forms. Monthly Measurements of Greatest Diameter and Total Increase (in centimetres) after Three Months.*

| No. | August. | September. | October. | November. | Increase. |
|---|---|---|---|---|---|
| 1 | 4·67 | 4·67 | 4·77 | 4·98 | ·31 |
| 2 | 4·25 | 4·47 | 4·78 | 5·00 | ·75 |
| 3 | 3·74 | 4·03 | 4·24 | 4·43 | ·69 |
| 4 | 3·68 | 3·92 | 4·25 | 4·50 | ·82 |
| 5 | 3·36 | 3·50 | 3·82 | 4·04 | ·68 |
| 6 | 3·28 | 3·30 | 3·36 | 3·67 | ·39 |
| 7 | 2·92 | 2·95 | 3·13 | 3·42 | ·50 |
| 8 | 2·81 | 3·00 | 3·39 | 3·60 | ·69 |
| 9 | 2·89 | 2·95 | 3·21 | 3·23 | ·34 |
| 10 | 2·84 | 2·89 | 3·10 | 3·28 | ·44 |
| 11 | 2·83 | 3·00 | 3·11 | 3·24 | ·41 |
| 12 | 2·81 | 2·95 | 3·16 | 3·41 | ·60 |
| 13 | 2·80 | .. | 2·96 | 3·13 | ·33 |
| 14 | 2·61 | 2·62 | 2·80 | 3·09 | ·48 |
| 15 | 2·60 | 2·68 | 2·80 | 3·15 | ·55 |
| 16 | 2·60 | 2·70 | 2·87 | 2·88 | ·28 |
| 17 | 2·56 | 2·64 | 2·80 | 2·99 | ·43 |
| 18 | 2·53 | 2·69 | 3·01 | 3·22 | ·69 |
| 19 | 2·53 | 2·58 | 2·82 | 3·04 | ·51 |
| 20 | 2·52 | 2·52 | 2·78 | 2·97 | ·45 |
| 21 | 2·52 | 2·66 | 2·87 | 3·21 | ·69 |
| 22 | 2·51 | 2·60 | 2·82 | 3·07 | ·56 |
| 23 | 2·50 | 2·47 | 2·68 | 2·94 | ·44 |
| 24 | 2·47 | 2·48 | 2·61 | 3·03 | ·56 |
| 25 | 2·47 | 2·52 | 2·84 | 3·12 | ·65 |
| 26 | 2·42 | 2·42 | 2·56 | 2·76 | ·34 |
| 27 | 2·36 | 2·42 | 2·64 | 2·89 | ·53 |
| 28 | 2·33 | 2·39 | 2·53 | 2·83 | ·50 |
| 29 | 2·19 | 2·20 | 2·43 | 2·66 | ·47 |
| 30 | 2·17 | 2·20 | 2·53 | 2·87 | ·70 |
| 31 | 2·08 | 2·08 | 2·22 | 2·50 | ·42 |
| 32 | 2·06 | 2·22 | 2·48 | 2·71 | ·65 |
| 33 | 2·05 | 2·12 | 2·44 | 2·64 | ·59 |
| 34 | 2·04 | 2·07 | 2·30 | 2·50 | ·51 |
| 35 | 2·01 | 2·17 | 2·36 | 2·48 | ·47 |
| 36 | 1·93 | 2·01 | 2·21 | 2·53 | ·60 |
| 37 | 1·97 | 2·03 | 2·14 | 2·50 | ·53 |
| 38 | 1·94 | 2·00 | 2·22 | 2·42 | ·48 |
| 39 | 1·80 | .. | 2·08 | 2·32 | ·52 |

The drawing of conclusions from these figures is hindered by the fact that regular fishing of the larger forms took place during the term of the Expedition on Low Isles. Old and large forms are therefore missing. However, it will be seen that:

(1) The mode moved from about 4 cm. in January to 5·4 cm. in July. That is, the growth was approximately 1·4 cm. in six months.

(2) There was an anomalous result for June, the figures being irregular, with apparently several modes. This is probably due to the fact that *Trochus* tends to hibernate during the cold months of the year, so that many escaped detection by remaining beneath the boulders and a representative sample was thus not obtained.

(3) There is a marked absence of very young and of very old animals. The young are most difficult to detect, as their colours blend so remarkably with those of the Lithothamnion-covered shingle. The smallest had a diameter of 1·47 cm. The older forms, as stated earlier, are regularly fished.

(4) The preponderance of 4 to 5 cm. animals in March points to there having been an extremely good fall of spat in 1927, with the subsequent survival of a large proportion of the individuals.

The third method of measuring growth was begun in January, 1929, after the failure of the first method. In this experiment free-living animals on the south-east edge were used. The animals were file-marked and numbered at the time of their measurement. The work was severely handicapped, because at first only night tides could be worked, and then the beginning of the wet season added to the discomforts.

One hundred and two animals, varying in diameter from 2 to 5 cm., were chosen. As soon as they were marked and measured they were placed back on or under the block where they were found. Each block was marked by a stake for future identification, but no fencing of any kind was constructed, so that the animals were free to wander.

TABLE III.—*Results of Measurements of some* 600 *Free-living* Trochus *given as Percentage Frequencies.*

| Group. | Percentage frequency. | | | | | | |
|---|---|---|---|---|---|---|---|
| | December. | January. | February. | March. | April. | May. | June. | July. |
| 2·00 cm. | .. | .. | .. | .. | .. | .. | ·1 | .. |
| 2·20 ,, | .. | .. | ·2 | .. | .. | .. | ·1 | ·1 |
| 2·40 ,, | .. | .. | 1·1 | ·3 | .. | .. | ·1 | ·3 |
| 2·60 ,, | ·2 | .. | ·9 | 1·5 | ·5 | ·3 | ·1 | ·5 |
| 2·80 ,, | ·5 | ·8 | ·5 | 3·0 | 1·3 | ·1 | ·5 | ·9 |
| 3·00 ,, | 2·1 | 1·3 | 2·0 | 4·3 | 2·6 | 1·1 | 1·8 | ·7 |
| 3·20 ,, | 4·8 | 2·5 | 2·7 | 3·1 | 4·9 | 2·1 | 2·2 | ·5 |
| 3·40 ,, | 11·5 | 4·5 | 2·0 | 2·6 | 4·8 | 2·9 | 1·3 | 1·7 |
| 3·60 ,, | 16·1 | 5·8 | 4·2 | 4·7 | 3·2 | 3·2 | 2·6 | 2·1 |
| 3·80 ,, | 13·5 | 7·8 | 5·5 | 6·5 | 2·6 | 4·5 | 4·2 | 2·1 |
| 4·00 ,, | 10·9 | 13·2 | 9·3 | 6·0 | 3·6 | 2·9 | 6·6 | 3·3 |
| 4·20 ,, | 9·3 | 9·2 | 13·3 | 8·1 | 6·0 | 4·8 | 6·9 | 4·0 |
| 4·40 ,, | 5·8 | 7·3 | 16·0 | 10·1 | 5·5 | 5·0 | 8·4 | 4·4 |
| 4·60 ,, | 3·7 | 6·8 | 12·6 | 9·6 | 6·6 | 6·7 | 5·0 | 5·2 |
| 4·80 ,, | 1·8 | 2·5 | 6·9 | 9·3 | 9·5 | 7·1 | 7·1 | 5·5 |
| 5·00 ,, | 2·4 | 2·5 | 5·2 | 6·1 | 11·1 | 10·0 | 4·5 | 6·8 |
| 5·20 ,, | 2·4 | 3·5 | 2·5 | 6·5 | 10·1 | 9·5 | 7·5 | 9·4 |
| 5·40 ,, | 2·4 | 3·6 | 2·0 | 3·1 | 7·8 | 9·7 | 5·5 | 10·9 |
| 5·60 ,, | 2·9 | 4·5 | 1·6 | 1·8 | 6·5 | 8·3 | 6·4 | 10·3 |
| 5·80 ,, | 1·3 | 5·6 | 2·5 | 1·1 | 4·8 | 7·3 | 10·4 | 9·6 |
| 6·00 ,, | 2·6 | 5·4 | 2·5 | 2·1 | 1·9 | 6·1 | 8·5 | 9·4 |
| 6·20 ,, | 1·5 | 4·0 | 1·1 | 1·0 | 1·0 | 2·6 | 5·0 | 4·8 |
| 6·40 ,, | 1·0 | 4·1 | 2·2 | 1·3 | 1·1 | 2·1 | 1·4 | 3·2 |
| 6·60 ,, | ·2 | 2·8 | 1·3 | 3·5 | 1·1 | 1·0 | 1·1 | 1·4 |
| 6·80 ,, | ·2 | 1·8 | 1·1 | 1·6 | ·8 | 1·0 | 1·0 | ·3 |
| 7·00 ,, | 1·0 | ·8 | ·6 | 2·0 | ·6 | ·5 | ·5 | ·6 |
| 7·20 ,, | ·2 | .. | ·2 | ·6 | 1·0 | ·1 | ·8 | ·6 |
| 7·40 ,, | ·2 | .. | ·2 | ·1 | ·8 | ·5 | ·3 | ·1 |
| 7·60 ,, | ·5 | .. | .. | .. | ·3 | ·3 | ·1 | ·6 |
| 7·80 ,, | ·8 | .. | .. | .. | ·1 | ·1 | .. | ·4 |

TABLE IV.—*Monthly Measurements of Free-living* Trochus *and Total Increase after Six Months (in Centimetres).*

| No. | January. | February. | March. | April. | May. | June. | July. | Increase. |
|---|---|---|---|---|---|---|---|---|
| 1 | 2·00 | 2·57 | 3·01 | .. | .. | .. | 3·95 | 1·95 |
| 2 | 2·12 | 2·56 | 2·95 | 3·33 | .. | .. | 3·73 | 1·61 |
| 3 | 2·60 | 3·20 | .. | .. | .. | 4·57 | 4·63 | 2·03 |
| 4 | 2·62 | 3·15 | 3·44 | 3·81 | .. | 4·31 | 4·37 | 1·75 |
| 5 | 2·66 | .. | 3·61 | 3·93 | .. | 4·50 | 4·57 | 1·91 |
| 6 | 2·75 | 3·25 | 3·64 | 4·00 | .. | 4·57 | 4·63 | 1·88 |
| 7 | 2·91 | 3·30 | 3·57 | 3·87 | .. | 4·42 | 4·54 | 1·63 |
| 8 | 2·91 | 3·37 | 4·20 | .. | .. | 4·60 | 4·81 | 1·90 |
| 9 | 3·05 | 3·65 | 4·04 | 4·41 | .. | 4·70 | 4·97 | 1·92 |
| 10 | 3·07 | 3·60 | 3·98 | 4·44 | .. | 4·93 | 5·00 | 1·93 |
| 11 | 3·10 | .. | 4·12 | 4·49 | .. | 5·02 | 5·06 | 1·96 |
| 12 | 3·13 | 3·56 | 3·75 | .. | .. | 4·28 | 4·40 | 1·27 |
| 13 | 3·20 | .. | 3·92 | .. | .. | 4·51 | 4·63 | 1·43 |
| 14 | 3·26 | .. | 4·29 | .. | .. | 5·21 | 5·32 | 2·06 |
| 15 | 3·45 | 4·03 | 4·37 | 4·66 | .. | 5·18 | 5·27 | 1·82 |
| 16 | 3·57 | 4·09 | 4·43 | 4·75 | .. | 5·20 | 5·20 | 1·63 |
| 17 | 3·60 | 4·14 | 4·32 | .. | .. | 4·90 | 5·06 | 1·46 |
| 18 | 3·61 | 4·14 | 4·53 | 4·86 | .. | 5·32 | 5·43 | 1·82 |
| 19 | 3·64 | 4·12 | 4·48 | 4·75 | .. | .. | 5·46 | 1·82 |
| 20 | 3·67 | 4·24 | .. | .. | .. | 5·32 | 5·42 | 1·75 |
| 21 | 3·70 | 4·30 | 4·60 | 4·91 | .. | 5·56 | 5·68 | 1·98 |
| 22 | 3.74 | 4·00 | 4·41 | 4·66 | .. | .. | 5·25 | 1·51 |
| 23 | 3·76 | 4·42 | 4·70 | 5·11 | .. | 5·76 | 5·81 | 2·05 |
| 24 | 3·91 | 4·31 | 4·60 | 5·00 | .. | 5·42 | 5·47 | 1·56 |
| 25 | 3·94 | 4·34 | 4·60 | 5·05 | .. | 5·57 | 5·64 | 1·70 |
| 26 | 3·96 | 4·25 | 4·43 | .. | .. | 4·94 | 5·01 | 1·05 |
| 27 | 3·97 | .. | 4·62 | 4·87 | .. | 5·16 | 5·17 | 1·20 |
| 28 | 3·97 | 4·33 | 4·76 | .. | .. | 5·26 | 5·27 | 1·30 |
| 29 | 4·09 | .. | .. | .. | .. | 6·10 | 6·20 | 2·11 |
| 30 | 4·13 | 4·57 | .. | .. | .. | 4·68 | 4·71 | ·58 |
| 31 | 4·46 | 4·83 | .. | .. | .. | 5·33 | 5·39 | 0·93 |
| | | | *Total Increase after Five Months.* | | | | | |
| 32 | 2·32 | 2·72 | 3·02 | .. | .. | 3·70 | .. | 1·38 |
| 33 | 3·02 | 3·58 | 3·78 | 4·20 | .. | 4·72 | .. | 1·70 |
| 34 | 3·31 | 4·04 | 4·41 | 4·65 | .. | 5·15 | .. | 1·84 |
| 35 | 4·34 | 4·72 | 5·02 | 5·37 | .. | 5·72 | .. | 1·38 |
| | | | *Total Increase after Four Months.* | | | | | |
| 36 | .. | 2·72 | 2·99 | 3·25 | .. | 3·72 | .. | 1·00 |
| 37 | .. | 3·44 | .. | .. | .. | 4·97 | .. | 1·53 |
| 38 | .. | 4·61 | .. | 5·17 | .. | 5·55 | .. | 0·94 |
| | | | *Total Increase after Five Months.* | | | | | |
| 39 | .. | 2·26 | 2·56 | 2·92 | .. | 3·40 | 3·47 | 1·21 |
| 40 | .. | 2·75 | .. | .. | .. | .. | 3·60 | 0·85 |
| 41 | .. | 2·77 | .. | 3·21 | .. | .. | 3·80 | 1·03 |
| 42 | .. | 2·83 | .. | .. | .. | .. | 3·88 | 1·05 |
| 43 | .. | 3·17 | .. | .. | .. | .. | 4·22 | 1·05 |
| 44 | .. | 3·32 | 3·67 | 4·02 | .. | 4·65 | 4·82 | 1·50 |
| 45 | .. | 3·73 | 4·05 | 4·49 | .. | 5·11 | 5·24 | 1·51 |
| 46 | .. | 3·86 | 4·25 | .. | .. | .. | 5·14 | 1·28 |
| 47 | .. | 3·99 | 4·32 | 4·55 | .. | 5·05 | 5·11 | 1·12 |
| 48 | .. | 4·11 | 4·36 | .. | .. | .. | 4·82 | 0·71 |
| 49 | .. | 4·19 | 4·58 | 4·98 | .. | 5·43 | 5·51 | 1·32 |
| 50 | .. | 4·52 | .. | .. | .. | 5·65 | 5·77 | 1·25 |

Each month, except May, as many as could be found were measured and the results listed. On July 22nd the final measurement was made, and only 43 of the original 102 animals were discovered. Twenty of them had disappeared at the first reading, so 20 immigrants were added to the number under observation. Twenty-nine seen on only one occasion after being marked and 23 seen twice have been excluded from the results as they are of no consequence.

Growth is very irregular, and animals of approximately the same diameter at the beginning of the experiment were found to differ frequently by as much as 0·5 cm. at the end of six months. This irregularity in growth will probably explain the irregularities in Table III, which shows the measurement of approximately 600 *Trochus*.

In Table IV the measurements of the animals in this experiment are given. Though great variations in growth-rate exist, it appears safe to assume that animals one year old are from 2·5 to 3 cm. in diameter, two years old are 5 to 6 cm., three years, 7 to 8 cm. Above this size, owing to the definite flattening out of the whorls, growth is probably very slow, but as few animals of large size were found, no age can be given for them. The writer cannot, however, agree with Hedley's statement that *Trochus* six months old are 2 in. (5 cm.) in diameter, and one year old are 3 in.

From these figures there is seen to be a definite slackening off in the amount of shell deposited by the animals during the colder months, and in one or two cases there has been a complete cessation in shell-deposition. This period is not only one of rest from shell-building; it can be termed a time of hibernating, for most *Trochus* feed but little and remain hidden below the boulders.

## 5. REPRODUCTION.

The sexes in *Trochus* are separate, and there is no external sexual difference. The method by which the sex can be determined is described on p. 146.

Weekly gonad samples were taken, using *Trochus* varying in diameter from 3 to 9 cm., and in all 400 animals were examined. Of 300 of these, 147 were males and 153 females. The remaining 100 were small forms ranging from 3 to 5 cm., used in order to find at what age the animals matured. These were all found to be immature, but many of the larger ones were so far advanced as to allow of their sex being readily determined. The result of this work points to the sexes being present in equal numbers, and to the fact that animals smaller than 5 cm. are, in general, immature.

The method of examining the gonad proved very wasteful, for the animals with the apex of their shell removed were open to the attacks of other animals and they soon died. Owing to these deaths, experiments on sex-change could not be carried out, so that the close examination of all gonadial products was adopted. In no case were sperm and eggs found together, though many instances of large eggs undergoing resorption mixed with small, developing eggs were found. This points to there being no change of sex in moderately young *Trochus*, but the matter requires further examination.

Many attempts to keep *Trochus* in captivity in an aquarium were made, but in every instance the animals soon showed signs of distress, and many valuable spawning animals were lost through persisting with this attempt. In order to hold these animals in captivity it was found necessary to place them in jars left out in the sea. There soon developed within the pots a strong growth of filamentous algae (*Enteromorpha* sp.), and on this growth the animals throve. Many *Trochus* so imprisoned in March were in good health in July.

The animals were visited daily, and on 22nd March, just as the flooding tide covered the jars, one animal was found extruding eggs. The temperature of the water was 28·2° C. The eggs are freed into the water and then float away, but in the still water within the jars they soon settled, floating again at the slightest stirring of the water.

The eggs of this specimen, as of others found later, were freed through the exhalent siphon as the foot was retracted. They were liberated a few at a time, and in no case were great clouds of eggs seen. *Trochus*, therefore, differs in this respect from *Haliotis* (Stephenson, 1924).

The laying operation appears to be protracted. One female first observed extruding eggs in June was still laying freely in late July. This animal was preserved, and on breaking the shell the ovary was seen to contain enormous numbers of eggs that readily washed free.

Only two males were actually observed extruding their products. The sperm was liberated in such quantities as to cause a cloudiness in the water caught up in the mouth of the shell, though there was no noticeable milkiness in the surrounding water.

*Trochus* appears, therefore, to be a winter-breeder, the season extending from March to July at least, and each animal possesses a protracted spawning period.

The eggs of *Trochus* at, and just before, extrusion are spherical. Before they are perfectly mature they are of irregular shape, owing to mutual pressure. Those taken from the ovary are each encased in three egg-cases. The outer one is regularly pitted, and gives to the egg a total diameter of 0·5 mm. Within the outer case is a second one, which becomes much more apparent in stale eggs as a cloudy coating. Next comes a transparent coat, which is clearly marked off from the other two, even in fresh specimens. In immature eggs the nucleus is easily discernible, but in mature ones the abundance of green yolk hides it.

The naturally extruded egg differs from those taken from the ovary in that the two outer cases are absent. The extruded egg (chorion included) has a diameter of 0·3 mm., of which the egg proper is 0·17 to 0·25 mm.

The sperm consists of a cylindrical head, rounded anteriorly and indented posteriorly, and a long flagellum. The head of the sperm is ·007 mm. long, and the tail is approximately five times as long as the head.

Artificial fertilizations, using the naturally extruded eggs and sperm, were effected. In four hours after mixing the products the first division had commenced. Division was equal. The stages following the first division were not observed, but in twenty hours after mixing many of the egg-cases contained ciliated embryos, the rapidly beating cilia causing the embryo to rotate slowly within the case. At this stage the experiment was left, and on returning to it later it was found that the young had completely vanished, many ciliates present in the bowls being probably responsible for the loss. No success attended many further attempts at fertilization.

An earlier worker on *Trochus*, Montague, who died before completing his experiments, was of the opinion (1915) that *Trochus* were not mature until they had reached a basal diameter of 8·5 cm. This would make these animals about three years old. The first animal that the writer observed extruding eggs was 7·83 cm. in base. From this moment all *Trochus* found on the reef were closely examined, particular attention being paid to those animals of 4 to 5 cm. base. Amongst the many found laying there were, in particular, those of the following diameters : 4·40, 4·80, 5·05, 5·80, 6·08 and 6·30 cm. amongst

the females, and 5·61 and 7·22 amongst the males. The 4·40 animal was found in the moat, where conditions for normal growth are not favourable, so that this specimen can be regarded as one of retarded growth.

*Trochus* seems, therefore, to become mature at two years old, that is, when the shell is in general 2 to 2·5 in. in basal diameter.

## 6. SUMMARY.

1. *Trochus* is a " scraping " gastropod.

2. It is essentially a littoral animal and can withstand protracted periods out of water.

3. There is a tendency towards zoning, the oldest animals being found at or about lowest springs mark.

4. Shell-growth is continuous, though there is a slackening off of shell-deposition during the winter months.

5. There was a marked absence of young forms from Low Isles.

6. The animals seem to roam fairly widely in search of food.

7. Animals of base 2·5 to 3 cm. are considered one year old, those of 5 to 6 cm. are two years old, and those of 7 to 8 cm. are three years old.

8. The sexes are present in equal proportions.

9. Though the smallest *Trochus* found laying eggs was 4·40 cm. in diameter, they are not, in general, mature until two years old.

10. The eggs are spherical, and are freed into the water a few at a time. The laying season certainly extends from March till July ; it is probably much more protracted.

11. Successful artificial fertilizations were carried out, though all stages in the development were not observed.

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